AD-A187 287

NAVAL POSTGRADUATE SCHOOL
Monterey, California

DTIC
SELECTED
NOV 3 0 1987
D
D

THESIS

OPTICAL MEMORY CARDS: A COMPARISON WITH
OTHER CURRENT TECHNOLOGIES AND POTENTIAL
MILITARY APPLICATIONS

by

Stephen H. Frink

September 1987

Thesis Advisor: B. A. Frew

87 11   3 292

Best
Available
Copy

A187 287

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION	1b RESTRICTIVE MARKINGS
Unclassified	

2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT
	Approved for public release; Distribution is Unlimited
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	

4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)

6a NAME OF PERFORMING ORGANIZATION	6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION
Naval Postgraduate School	Code 54	Naval Postgraduate School

6c ADDRESS (City, State, and ZIP Code)	7b ADDRESS (City, State, and ZIP Code)
Monterey, California 93943-5000	Monterey, California 93943-5000

8a NAME OF FUNDING/SPONSORING ORGANIZATION	8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS			
	PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
OPTICAL MEMORY CARDS: A COMPARISON WITH OTHER CURRENT TECHNOLOGIES AND POTENTIAL MILITARY APPLICATIONS (u)

12 PERSONAL AUTHOR(S)
Frink, Stephen H.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year Month Day)	15 PAGE COUNT
Master's Thesis	FROM ___ TO ___	1987 September	48

16 SUPPLEMENTARY NOTATION

Cont'd from pg 3

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Optical memory card; Laser card; Integrated circuit (IC) card; Smart card; Magnetic stripe card; Optical mass storage systems

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

As the industrialized nations of the world move further into the Information Age, the storage and distribution of information becomes increasingly more critical to the success of our daily endeavors. No where is this more apparent than in the military community. As the amount of information each military unit must have to function efficiently and effectively increases, so does the space required to store it. This situation has prompted at least one high-level Navy official to initiate a program to test the concept of a "paperless ship" by 1990. At the head of the list of systems to meet the mass storage requirements of the program are the opcical memory technologies. Included under this heading are the optical memory cards. An optical memory card is the size of a standard 54mm x 85mm wallet card and, in one particular configuration, is capable of storing 800 pages of text alone or 200 pages of combined text and graphics. Employing optical memory card technology in the "paperless ship" will reduce the space required to store technical manuals and directives by a factor of over 200! Two applications; A Technical Document Publishing, Distributing and Update Program; and An Individual Personnel Record Storage and Update Program are discussed as potentially beneficial to the military community.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	Unclassified

22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code)	22c OFFICE SYMBOL
Prof. B. A. Frew	(408) 646-2924	Code 54Fw

DD FORM 1473, 84 MAR   83 APR edition may be used until exhausted   SECURITY CLASSIFICATION OF THIS PAGE
All other editions are obsolete

1

Optical Memory Cards: A Comparison with
Other Current Technologies and Potential
Military Applications

by

Stephen H. Frink
Lieutenant, United States Naval Reserve
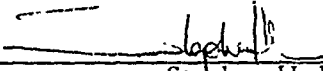B.A., University of South Florida, 1980

Submitted in partial fulfillment of the
requirements for the degree of

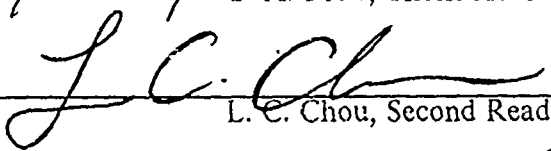MASTER OF SCIENCE IN INFORMATION SYSTEMS

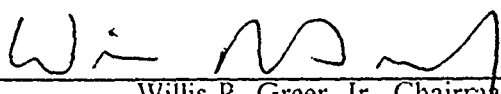from the

NAVAL POSTGRADUATE SCHOOL
September 1987

Author: _____
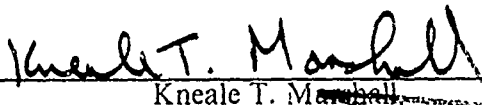Stephen H. Frink

Approved by: _____
B. A. Frew, Thesis Advisor

_____
L. C. Chou, Second Reader

_____
Willis R. Greer, Jr., Chairman,
Department of Administrative Sciences

_____
Kneale T. Marshall,
Dean of Information and Policy Sciences

ABSTRACT

As the industrialized nations of the world move further into the Information Age, the storage and distribution of information becomes increasingly more critical to the success of our daily endeavors. No where is this more apparent than in the military community. As the amount of information each military unit must have to function efficiently and effectively increases, so does the space required to store it. This situation has prompted at least one high-level Navy official to initiate a program to test the concept of a "paperless ship" by 1990. At the head of the list of systems to meet the mass storage requirements of the program are the optical memory technologies. Included under this heading are the optical memory cards. An optical memory card is the size of a standard 54mm x 85mm wallet card and, in one particular configuration, is capable of storing 800 pages of text alone or 200 pages of combined text and graphics. Employing optical memory card technology in the "paperless ship" will reduce the space required to store technical manuals and directives by a factor of over 200! Two applications; A Technical Document Publishing, Distributing and Update Program; and An Individual Personnel Record Storage and Update Program are discussed as potentially beneficial to the military community. Keywords: data storage systems; theses; memory devices

cont'd

pg 1

3

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

A.   GENERAL

The 'paperless ship' is a modern naval frigate without paper technical manuals, directives, report forms or memoranda. The target date for making this concept a reality is 1990 and it is gaining acceptance at high levels in the Department of the Navy (DON). Vice Admiral Joseph Metcalf, Deputy Chief of Naval Operations for Surface Warfare, author of the "paperless ship" concept, commented on the over 41,000 pounds of paper required to operate the modern naval frigate in a recent interview [Ref. 1: p. A-17]. "We do not shoot paper at the enemy. . . . it does not contribute to war-fighting. Storing information in books and manuals and documents detracts from war-fighting. It's heavy. It's not in a form that can be used." he said. His sentiments are echoed by Rear Admiral Harry S. Quast, director of the Navy Information Systms division of the Pentagon. [Ref. 2: p. D-1]. He said, ". . . now we think this technology is the way to go. . . . We may find out those laser cards work much better [than CD-ROM]. . . ."

On a larger scale, the Department of Defense (DOD) has begun development of an integrated DOD Computer-aided Acqusition and Logistic Support (CALS) Program which will establish standards for contracting and implementing for future weapon and data system acquisitions. There will be a need as the CALS program develops for a high-data-density, low-weight and cube mass storage media to store and distribute the data generated by CALS. See Ref. 3 for a description of the CALS program.

The laser card RADM Quast is referring to above is a form of optical mass storage medium known as an optical memory card. With the optical memory card, as with some other types of optical storage, digital data is read from or written to the card using the beam from a semiconductor laser. However, the optical memory card can also be pre-recorded using a photolithographic process which allows them to be duplicated in large quantities virtually over-night, much like a newspaper. The optical memory card would be one of several optical memory media that could conceivably be included in the CALS program standard for digital storage media.

As the search continues for a media to store and distribute the vast amount of information the military needs to function effectively in this Information Age, the

military community will have to take a more serious look at what may now be categorized as "exotic" technology. Optical memory cards offer a great deal of potential in this area and are rapidly gaining acceptance in the optical data storage industry.

B. OBJECTIVES

This thesis was written with three basic objectives in mind:

- Introduce the reader to optical memory cards as a technology
- Compare optical memory cards with other, more familiar and better established memory card technologies
- Describe two potential application areas where optical memory card systems could be developed quickly and yet have a profound effect on the military community

The conception and development of the optical memory card, along with background information for the Integrated Circuit (IC) card and the Magnetic Stripe Card (MSC), will be discussed in Chapter II. The three technologies will be compared in the areas of Data Capacity, Data Security, Hardware Requirements and Economic Factors in Chapter III. In Chapter IV, two potential military applications will be discussed which could be successfully implemented using optical memory card technology: A Technical Document Publishing, Distribution and Update Program; and An Individual Personnel Record Storage and Update Program. These applications were chosen because they are technologically accessible and would provide potential benefits over a wide range of military communities.

C. RESEARCH METHODOLOGY

The research methodology used in preparing this thesis was primarily a review of available literature to develop a working knowledge of the topic. A thorough search of mostly periodical publications was conducted to collect the background material. This background material was then analyzed to produce the comparison data and synthesize the applications. Written materials were often followed up by telephone conversations with industry personnel. The comparisons presented are intended to be objective and provide the reader with a sense of the application domains associated with each memory card technology discussed.

Finally, the applications were chosen after careful consideration of the results of the analysis and are programs which the author considers to be the best areas for successful implementation of an optical memory card system at a minimal cost using off-the-shelf technology where available.

9

II. BACKGROUND

This chapter will introduce the technological and economical characteristics of optical memory cards, IC cards, and magnetic stripe cards. They are presented in the context of providing the reader the necessary information to comfortably digest the discussion of comparisons between them. Optical memory cards and IC cards will be presented in greater detail than magnetic stripe cards in order to better familiarize the reader with these newer technologies.

A. OPTICAL MEMORY CARDS

The optical memory card is the brainchild of Jerome Drexler. In 1968 Drexler left Bell Laboratories to start Drexler Technology Corporation (DTC). DTC specializes in optical data products and has been instrumental in the growth of the computer industry as a leading independent supplier of materials used in the manufacture of integrated circuits. [Ref. 4: p. 4]

In August 1978 DTC introduced the concept of the optical memory card [Ref. 5: p. 120] and made their first optical memory card product, *LaserCard®* available in engineering quantities in 1981 [Ref. 6: p. 1]. DTC's strategy for commercializing the optical memory card is to focus its efforts on the development of the media and relies on its licensees to develop viable systems. In late 1982 DTC commissioned Stanford Research Institute to develop the basic technology for reading and writing the cards and sells that information with its licenses [Ref. 5: p. 121]. The optical recording media DTC uses in it's optical memory cards is a patented DTC product called the *Drexon Media®*. Drexon® is created from the chemical conversion of high resolution photographic emulsions using a proprietary process that produces a thin film or crust of silver particles near the surface of an organic film or colloidial matrix. (See Figure 2.1) An underlayer of essentially the same material, without the silver particles, serves to thermally isolate the crust, increasing laser efficiency during write operations and reflective contrast during read operations. These two layers are protected by an encapsulation layer of thick, transparent polycarbonate material. [Ref. 7: p. 62].

Writing on the optical memory card is accomplished in two ways, by laser recording and/or by high-speed photolithography. When using a laser to record data

10
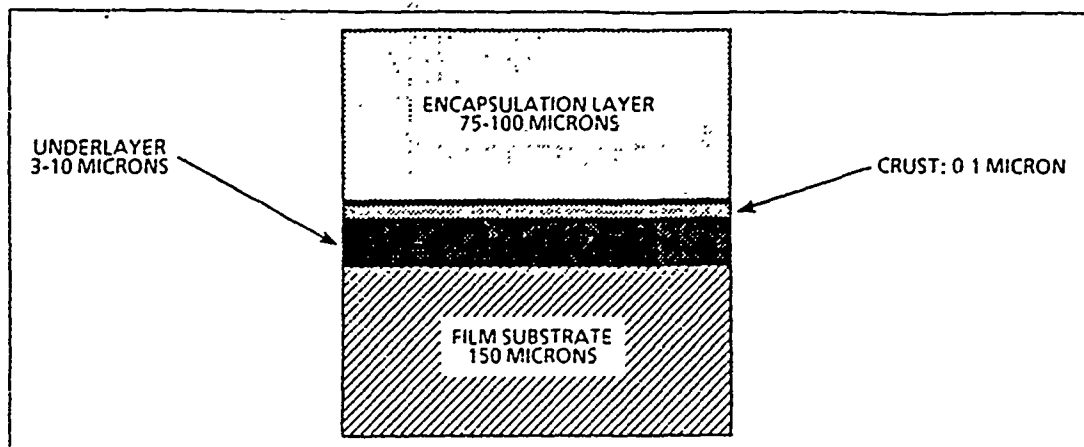
Figure 2.1 Construction of the Recording Medium.

on a card the crust of the Drexon® material is heated above 200° C causing the organic colloidial matrix to melt and form a pit into the underlayer (See Figure 2.2).
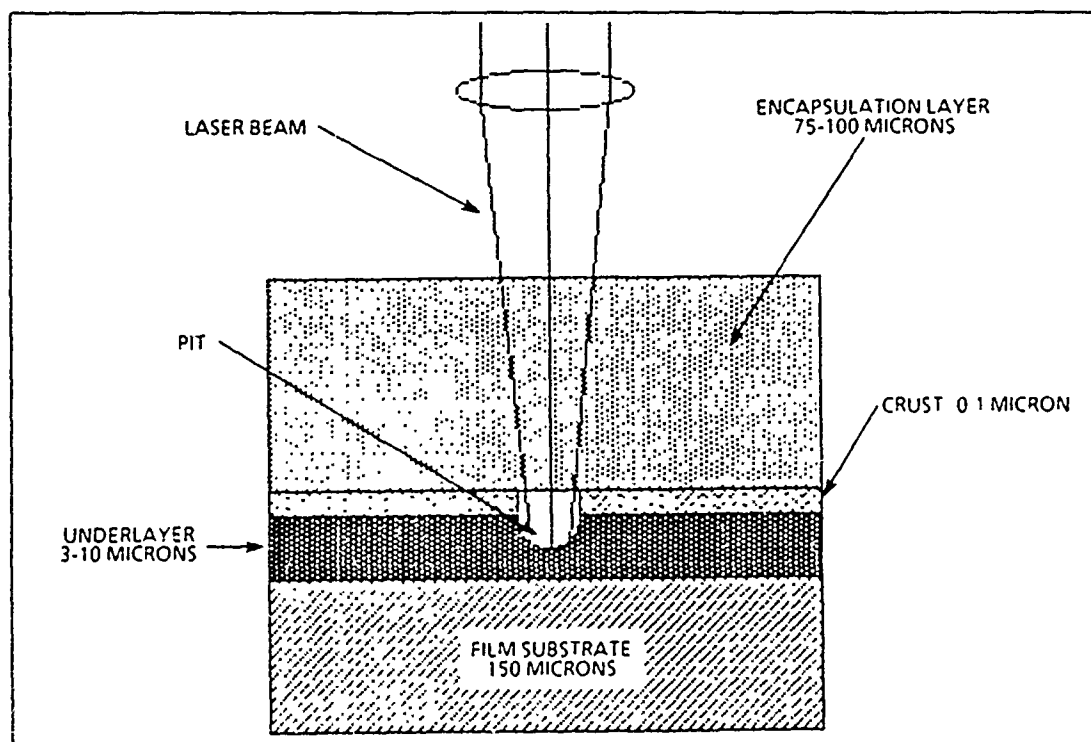
Figure 2.2 Laser Writing Operation.

This can be accomplished using an inexpensive, semiconductor laser (typically 5 milliwatts) and opto-mechanical scanning system (See Figure 2.3). During certain

11

stages of manufacture, the photographic emulsions used in the Drexon® material are light sensitive. This property allows DTC to
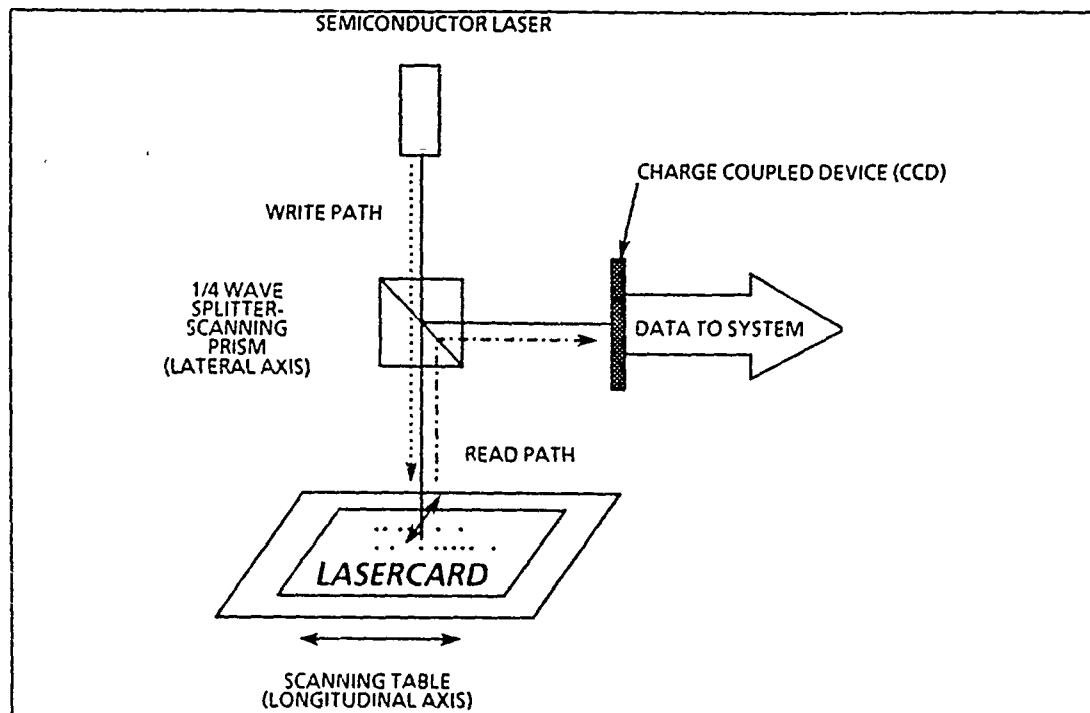
Figure 2.3 Typical Laser-Optical Read/Write System.

pre-record cards using the same photomask mastering techniques used in the manufacture of integrated circuits. Using this process, read-only and laser-updatable cards can be literally "printed" in large quantities. In fact, all of DTCs optical memory cards are pre-formatted at the time of manufacture using this process. The optical memory card is read using a light source, usually an incandescent light source or semiconductor laser (low-power mode), and a photo-detector array or Charge-Coupled Device (CCD). Data is decoded from the card by measuring the reflectivity of the crust layer (typically 40%) and essentially reading the pits created by the write process.

DTC manufactures the Drexon Media® in 16mm and 35mm widths. The optical memory card is essentially a stripe of Drexon® material mounted on a standard 54mm X 85.5mm wallet card (See Figure 2.4) and manufactured by DTC in three basic configurations: A single stripe of 16mm or 35mm of Drexon® on one side, A 35mm stripe of Drexon® on both sides. A dual-function card with both a magnetic stripe in the American National Standards Institute (ANSI) position [Ref. 8: p. 4] and an

12
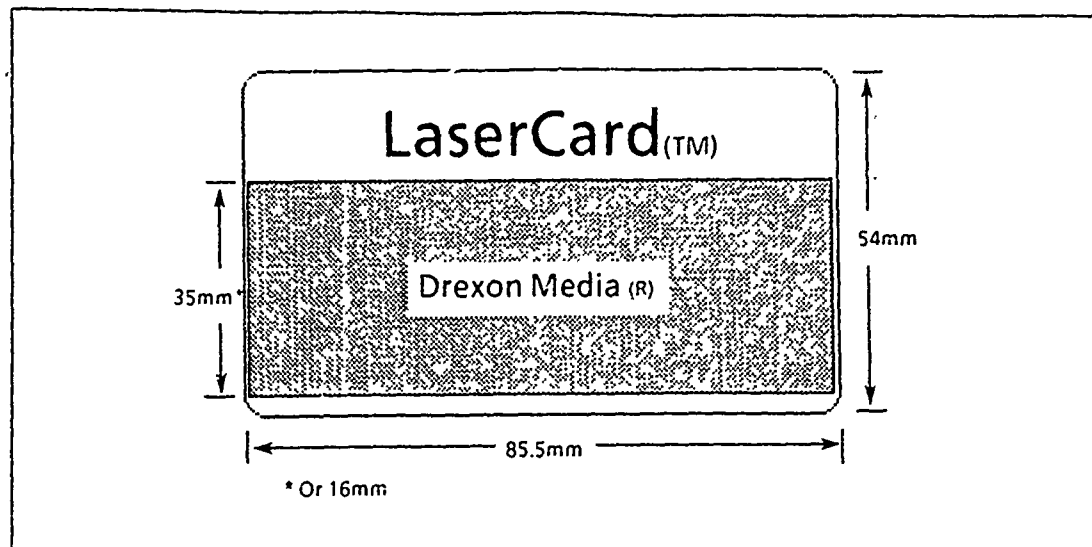
Figure 2.4   Typical Optical Memory Card.

optical stripe on one side. The dual function card is intended to be compatible with transaction terminals not yet equipped to use the optical stripe. Formatted capacities for the cards (using 10 micron pits) are: 625 kbytes for cards with a single 16mm stripe, 2.2 Mbytes for cards with a single 35mm stripe (4.4 Mbytes both sides covered), and 625 kbytes optical and 212 bytes of magnetic storage on a dual-function card [Ref. 7: p. 65]. Pit size could theoretically be reduced to less than 1 micron. A 0.4 micron pit size would yield a capacity of over 200 Mbytes per card. This is currently not being considered by the industry due to the increased hardware costs involved and DTC market research indicating a marginal demand for a card-sized storage medium with a capacity greater than 20 Mbytes [Ref. 9: p. 1].

Quantity costs for cards run from $1.00 each for blank cards to around $5.00 each for 2.2 Mbyte pre-recorded cards. For large runs of identical cards the most cost effective method of duplication is to have Drexler master, format and duplicate the cards. Equipment suitable for on-demand publishing of up to 500 cards will cost around $10,000. For publishing or updating small numbers of cards, several of DTC's licensees have announced plans for marketing laser reader-writer units using a Direct-Read-After-Write (DRAW) recording process that will cost in the area of $500 - $1000. Read-only equipment for reading pre-recorded cards will cost around $200. Some of these companies intend to market their equipment commercially in the Qtr. 3 - Qtr. 4, 1987, timeframe. [Ref. 10: p. 289]

13

DTC is currently working with its licensees to provide second-source opportunities for the manufacture of their optical memory cards.

B.   INTEGRATED CIRCUIT CARDS

The integrated circuit card, or "Smart Card" as it is called by the consumer electronics industry, was first introduced commercially in 1974 by French journalist and inventor Roland Moreno [Ref. 11: p. 75]. An IC card is essentially a standard 54mm X 85.5mm wallet card with one or more integrated circuit chips imbedded in it. Most cards are manufactured to International Standards Organization (ISO) standards [Ref. 12: p. 2] incorporating a magnetic stripe and embossing area to retain compatability with existing equipment (See Figure 2.5). Some recently developed cards
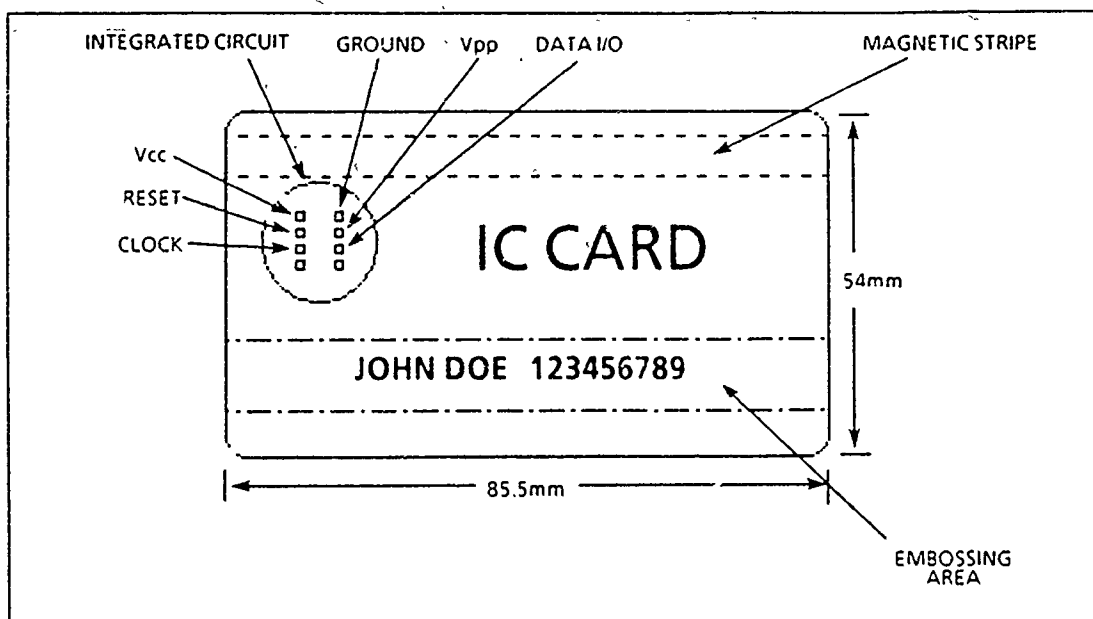
Figure 2.5   Typical IC Card.

contain a transducer to simulate the signal usually generated by the magnetic stripe. [Ref. 13: p. 35]. External connections to the chip are made through the eight galvanic contacts shown in Figure 2.5 These contacts provide power (Vcc), a reset signal, a clock signal, data Input and Output (I/O) signals, a programming voltage (Vpp), and a circuit ground. Two of the contacts called for in the standard are for future expansion and currently unused. IC cards are manufactured in two configurations; with and without an on-card microcomputer. Cards without a microcomputer contain essentially an I/O interface, some memory access logic and some form of non-volatile memory, usually Erasable Programmable Read-Only Memory (EPROM) which must

14

be erased using ultraviolet light or Electrically Erasable Programmable Read-Only Memory (EEPROM) which is erased by a programming voltage from the terminal (See Figure 2.6). These cards are primarily used in applications where a requirement exists

```
CONTACTS *
   │
   ▼
DATA I/O  ▨ ──────────────┐  ┌──────────────┐
                          │  │  SERIAL I/O  │
CLOCK     ▨ ──────────────┼──┼──────────────┤
                          │  │   CONTROL    │
RESET     ▨ ──────────────┘  │    LOGIC     │
                             ├──────────────┤
                             │    EPROM     │
                             │      OR      │
                             │   EEPROM     │
                             └──────────────┘

       *Vcc, Vpp (EEPROM only) and Ground not shown
```
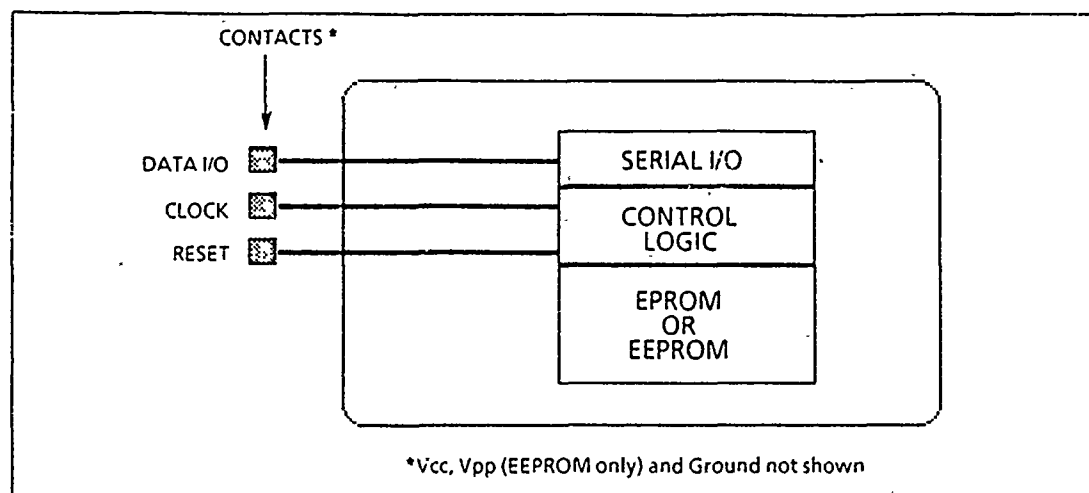
Figure 2.6   Contents of the Memory-Only IC Card.

for a simple memory I,O function with a minimum of data security. An example would be an electronic combination key or a simple debit card for use in a financial transaction system. Cards incorporating a microcomputer consist of essentially a Microcomputer Unit (MCU) and some form of non-volatile memory. The on-card system may be implemented as a single chip or several chips. A single chip implementation is preferred by industry because it provides the most reliable and cost effective design. A single chip implementation also has certain advantages in the area of data security, which will be discussed in the next chapter. [Ref. 12: p. 2-3]

The actual configuration of the MCU itself depends heavily on the requirements of its intended application. Most applications require, as a minimum: A Central Processing Unit (CPU), some working Random Access Memory (RAM), some program(s) stored in Read-Only Memory (ROM), some serial I/O control logic, and some form of non-volatile memory such as EPROM or EEPROM (See Figure 2.7). [Ref. 14: p. 2-4] Some of the more sophisticated cards currently available also include a keyboard and an alphanumeric display. Most MCU's used in IC cards are 8-bit computing devices. The main function of the MCU is to control access to the non-volatile memory and/or perform operations on data contained in the non-volatile memory. The MCU accomplishes this by executing program routines stored in the program ROM.

15

CONTACTS *

DATA I/O

CLOCK

RESET

SERIAL I/O

CPU

RAM

ROM

EPROM
OR
EEPROM

*Vcc, Vpp (EEPROM only) and Ground not shown
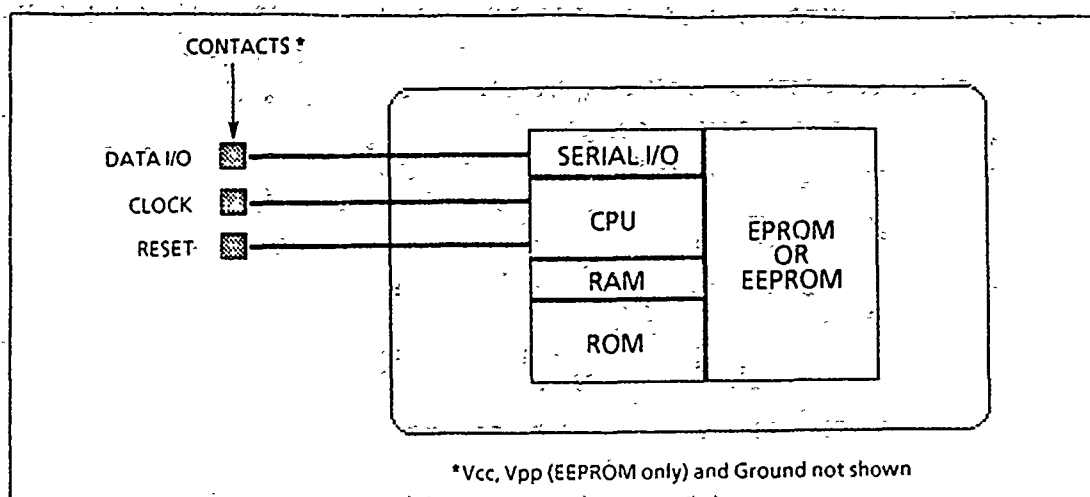
Figure 2.7   Contents of the MCU IC Card.

The complexity of these routines is dependent on the application the card will be used in. Because the MCU can be programmed for different functions, non-volatile memory can be segmented and access to the various segments controlled at different levels by the MCU. For example, in an Electronic Funds Transfer (EFT) application memory could be segmented into Unconditional, Confidential and Secret access zones. (See Figure 2.8) The Unconditional access zone would allow unconditional read access to data such as: Name, Address, Telephone Number and Account Number. The Confidential access zone would allow conditional read/write access to data such as: Merchant ID, Date of Transaction, and Amount of Purchase (Audit Trail). The Secret access zone would be conditionally accessible for read-only operations on data such as: Cardholder's Personal Identification Number (PIN), ID of the issuing agency, Manufacturer's Code, Card Serial Number and the Starting Account Balance. [Ref. 12: p. 3]

The ability for the IC card to function autonomously of a host computer is seen as a valuable asset by the banking industry and has led to several pilot studies using the IC card as an off-line EFT device [Ref. 15: p. 34-35].

IC cards are manufactured in the United States, Europe and Japan. Pricing is a function of card features and memory capacity. Current prices for quantity orders range from $3.00 - $5.00 each for 8 kbyte cards to $8.00 for a 16 kbyte card and $20.00 for a 16 kbyte card with a keypad and display (Japan) [Ref. 15,16: p. 41,35]. IC card reader/writers average about $100.00 each for installation in on-line terminals and less

16

```
┌─────────────────────────────────────────────────────────────────┐
│                    Non-Volatile Memory                            │
│   ┌──────────────────────────────┐                                │
│   │ Cardholder Name              │      UNCONDITIONAL             │
│   │ Cardholder Address           │         ACCESS                │
│   │ Cardholder Telephone No.     │          ZONE                 │
│   │ Cardholder Account Number    │       (Read-Only)             │
│   │                              │                                │
│   ├──────────────────────────────┤                                │
│   │ Merchant ID                  │      CONFIDENTIAL             │
│   │ Date and Time of Transaction │         ACCESS                │
│   │ Amount of Purchase           │          ZONE                 │
│   │                              │       (Read/Write)            │
│   ├──────────────────────────────┤                                │
│   │ Cardholder PIN               │         SECRET                │
│   │ Issuing Agency ID            │         ACCESS                │
│   │ Manufacturer's Code          │          ZONE                 │
│   │ Card Serial Number           │       (Read-Only)             │
│   │ Starting Account Balance     │                                │
│   └──────────────────────────────┘                                │
└─────────────────────────────────────────────────────────────────┘
```

Figure 2.8 Memory Segmentation for a Financial Transaction Card.

than S40.00 each in quantities for units that would connect to an off-line terminal or personal computer [Ref. 17,13: p. 19,35].

C.   MAGNETIC STRIPE CARDS

The concept of the magnetic stripe card (MSC) has been in use in the banking industry since the early 1970's with IBM as a major force in its development [Ref. 18: p. 62]. The MSC was follow-on technology to machine readable embossing systems already in use for financial transaction cards. The technology was developed out of a need for higher data densities on credit cards to meet the informational requirements of the banking industry. In 1974 the ANSI standard for financial transaction cards contained two read-only tracks, one high-density track (Track 1) and one low density track (Track 2). In 1980 a standard was established for a third track with high density read/write capabilities. The current MSC is essentially a 10.28mm (minimum) stripe of standard magnetic material mounted on a 54mm X 85.5mm wallet card (See Figure 2.9) [Ref. 19: p. 10].

Industry standards for bit density and data encoding can be found in Ref. 8 . Using the standard, Track 1 would have a capacity of 335 bits, Track 2 would have a density of 235 bits and Track 3 would have a capacity of 658 bits for a total of 1228

17

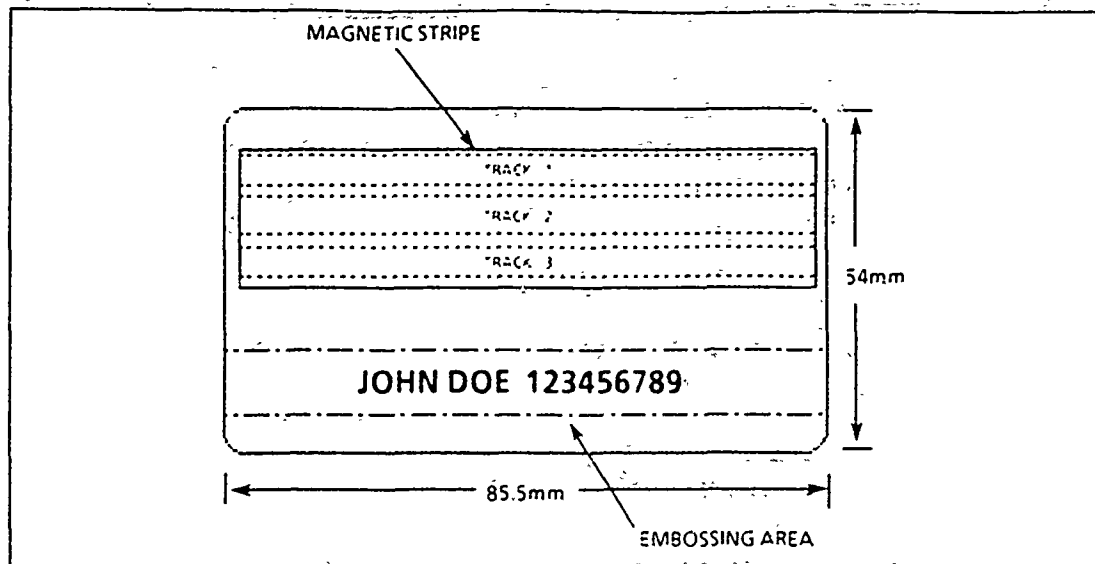Figure 2.9 Typical Magnetic Stripe Card.

bits or 153 bytes. Using higher density recording techniques this could be increased slightly. With the proliferation of the MSC into the world financial market more than 15 years ago, availablity of the medium is not an issue. At $0.50 each in quantities, neither is price.

III. COMPARING THE TECHNOLOGIES

It will soon become apparent, if not already, that the magnetic stripe card (MSC) is not in the same competitive league in terms of capacity and functional capability as the other two memory card technologies discussed. The reasoning behind including the MSC in the study was to provide a well-known and widely accepted technology for the reader to use as a reference point in the following discussions.

A. DATA STORAGE CAPACITY

This section will discuss the data storage capacities of the technologies presented in Chapter 2, using an example application wherever possible. First, a review of the published data storage capacities of each technology.

1. Optical Memory Cards

Optical memory cards are currently available with the following capacities [Ref. 7: p. 65]:

- Single 16mm optical stripe - 625 kbytes (Formatted)
- Single 35mm optical stripe - 2.2 Mbytes (Formatted)
- 35mm optical stripe on both sides - 4.4 Mbytes (Formatted)
- Dual function card: 16mm optical stripe and ANSI magnetic stripe - 625 kbytes optical, 212 bytes magnetic

These numbers assume a 10 micron pit size. It is possible to reduce the pit size to less than 1 micron, but this would require a substantial increase in hardware cost. DTC is currently working on a higher density card that would provide an 8 Mbyte capacity and capacities of 10 Mbytes or more are theoretically possible by simply increasing the total surface area of the card that is covered by the recording media [Ref. 20]. The optical memory card will be considered a high-density storage medium for the purposes of the following discussions.

2. Integrated Circuit Cards

Integrated circuit (IC) cards are available with a wide variety of capacities. This is due to the fact that a particular card is usually designed to meet the needs of a particular application. Some of the more popular memory sizes are 2, 8 and 16 kbytes for MCU cards. Memory-only cards are available with capacities up to 64 kbytes. [Ref. 15,16: p. 41,35] For the purposes of the following discussions the IC card will be considered a medium-density storage device.

19

3. Magnetic Stripe Cards

In its current form the magnetic stripe card (MSC) has a capacity of 153 bytes in ANSI format [Ref. 8]. This could be increased to over 200 bytes using higher density recording formats. The MSC will be considered a low-density data storage medium for the purposes of the following discussions.

4. Comparison of Data Storage Capacities

As a high-density storage medium the optical memory card is best suited for the storage and distribution of relatively large amounts of data. A 2.2 Mbyte optical memory card holds the equivalent of 800 pages of text or 200 pages of graphics and text combined. Some applications for a storage medium with this amount of capacity would be:

- Distribution of information from large, centralized databases to smaller regional databases
- Distribution and update of technical manuals and other publications
- Storage and update of personnel service, pay and medical records in a much more convenient and transportable form than the current paper method
- Very high security restricted access systems that require large amounts of storage for recording biometric data such as voiceprint, fingerprint and signature analysis used to positively identify the cardholder

As a medium-density storage device the IC card is best suited for applications within its memory capacity that require a minimum of off-card electronics such as:

- Personal identification tags/badges not requiring the storage of biometric data
- Electronic access keys for restricted access systems. Codes could be changed electronically without the knowlege of the cardholder
- Encoding keys for cryptographic equipment. Keys could be encoded electronically without the aid of a human operator, as in the present system

As a low-density data storage medium the MSC is best suited for applications requiring a minimum of data storage and a minimum of security. An example application would be an on-line exchange/commissary privilege verification card.

In the area of data storage capacities the three technologies discussed naturally fall into distinct categories (See Table 1). The low, medium and high-density categories each have their own application areas which suit them best. These application areas could theoretically overlap, but usually not in an effective and efficient manner. Using an optical memory card in an MSC application, for example, could be considered "capacity overkill" and probably would not prove to be advantageous from an economic standpoint as well.

```
TABLE 1
COMPARISON OF DATA STORAGE CAPACITIES

OPTICAL MEMORY CARD*
    (Pre-formatted)
Single 16mm stripe - 625 kbytes
Single 35mm optical stripe - 2.2 Mbytes
Dual-sided 35mm optical stripe - 4.4 Mbytes
Dual Function Card - 625 kbytes optical, 212 bytes magnetic

INTEGRATED CIRCUIT (IC) CARD*
MCU Cards - 2, 8, 16 kbytes
Memory Only Cards - Max. 64 kbyte

MAGNETIC STRIPE CARD (MSC)
Three Track ANSI Standard - 153 bytes
High-density Format - 212 bytes

* Increases with advances in technology.
```

B. DATA SECURITY

This section discusses the data security issues associated with memory card technologies. The discussion will focus on two specific areas: Physical Security and Logical Security. The strengths and weaknesses of each technology will be covered as they relate to these two areas. Physical security will address the following issues:

- Physical access methods of each technology and their security implications.

- Environmental Factors - Temperature, Electromagnetic Pulse (EMP), Electromagnetic Interference (EMI) [Including Radio Frequency Interference (RFI)], X-rays and Electrostatic Discharge (ED).

- Intentional, Unintentional destruction of data stored on the card.

Logical Security will address the following issues:

- System Access and Access Leveling.

- Data Encoding - Encoding and algorithmic encryption schemes.

1. Physical Security

Physical security, in the context of this study, deals with the physical aspects of a particular medium as they relate to protection of the data contained in the medium. In other words, how secure is the data stored in a particular medium from compromise or loss through physical access operations, environmental factors and intentional or unintentional destruction.

21

a. Physical Access Methods

The first issue is physical access method. Compromising emanations are most likely to occur during access operations, resulting in compromise of the data stored on the card. Compromising emanations are intelligence bearing signals which, if intercepted, could possibly be analyzed to disclose the content, classified or otherwise, of the information received. TEMPEST is an unclassified short name that refers to investigations and studies of compromising emanations [Ref. 21: p. A-6].

(1) *Optical memory Cards.* The optical memory card is accessed using a system similar to the one shown in Figure 2.3. The card itself is written to or read using the beam generated by the semiconductor laser. The only sources for TEMPEST violating signals occur in the circuitry prior to the semiconductor laser and following the CCD. One drawback unique to the optical memory card and optical memory systems in general is the effect of surface damage or obliterations on the accuracy of data write/read operations. The relative thickness of the encapsulation layer (See Figure 2.1) serves to keep small scratches and surface dust from appearing in the focal plane of the laser beam as it is focused on the optical media in an attempt to reduce the amount of error introduced by these contaminants. However, a defect large enough to eclipse a substantial portion of the laser beam can cause data to be misrepresented during write/read operations. The impact of such errors is a function of the software used to interpret the data in terms of the error detection and correction codes employed. The ability of these codes to recover lost or misrepresented data determines how much of an obliteration the system will tolerate.

(2) *Integrated Circuit Cards.* The IC card is usually accessed through the eight galvanic contacts located on the front or back of the card. In some unique applications the card is accessed using wireless technologies [Ref. 22: p. 78]. These systems were not considered by this author to be appropriate for a military TEMPEST environment and therefore are not discussed here. Because the IC card employs active components it presents more opportunities for data compromise during access operations. This problem is especially pronounced in cards designed using more than one chip (See Figure 3.1).

In this configuration, each CPU request to a separate memory chip must traverse a data bus external to the CPU, thereby generating compromising emanations [Ref. 12,14: p. 3,4]. The same argument could be used for the serial I/O bus used to communicate with the card. In essence, the IC card has the potential for
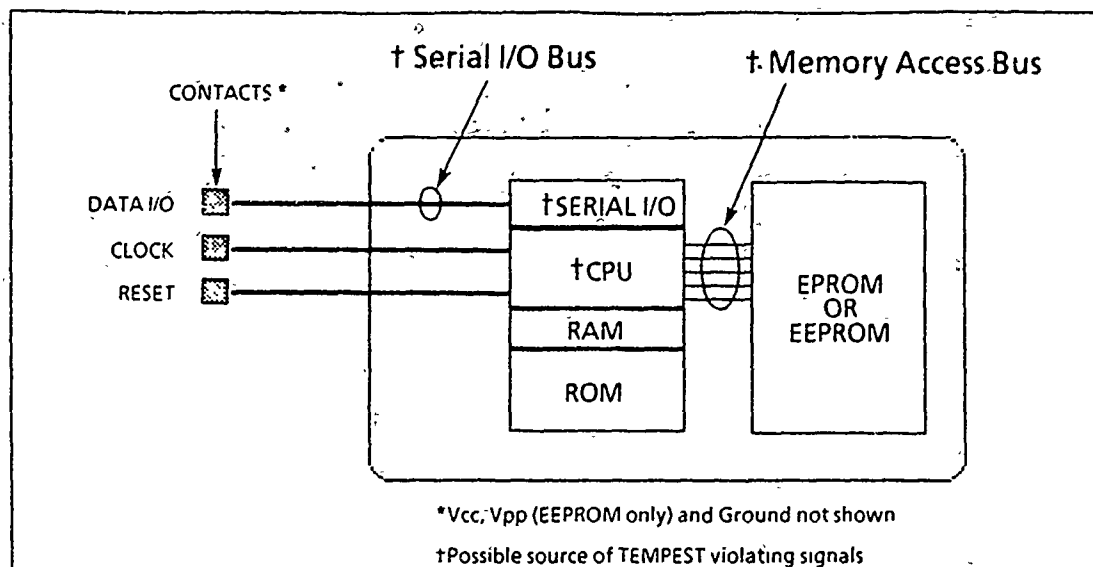
22

Figure 3.1   IC Card Incorporating More Than One Chip.

compromising sensitive data if not used in a sufficiently TEMPEST hardened environment. The IC card does present tremendous potential for use in high-security systems, assuming the physical security drawbacks can be solved for a given application. This topic will be discussed in greater detail in the section on Logical Security. It should also be noted that the advanced computing capabilities of third generation IC cards, those incorporating keyboards and displays, enable them to be used in stand-alone applications without the need for a separate terminal. The system functions are essentially performed by the card itself.

(3) *Magnetic Stripe Cards.*   Access to the data stored on an MSC is gained through the physical contact of the magnetic stripe with a magnetic read/write head installed in an appropriate device. Like the optical memory card, the MSC contains no active components. The proliferation of inexpensive MSC read/write equipment and the relative simplicity of the technology has resulted in the creation of some highly lucrative counterfeiting and fraud schemes that cost the U.S. banking industry well over $300 million a year [Ref. 17: p. 18]. Some security advances were made in the mid-1970's using infrared identification systems [Ref. 23: p. 62] and more recently magnetic watermark technonology [Ref. 24: p. 101]. These techniques provided additional security by making each card unique.

(4) *Comparison of Physical Access Methods.*   The primary issue under physical access methods is whether the particular technology is a passive or active

storage medium. The passive technologies, optical memory card and MSC, provide nothing more than data storage capabilities. Without any on-card active components the card itself cannot generate any compromising signals. The optical memory card, because of its unique manufacturing process, is difficult to counterfeit. Even though the data pits are visible, data is difficult to compromise because in order to do so one must have a knowledge of the system context and encryption/encoding techniques used to record the data in order to decode the data once it is read. The optical stripe cannot be removed from the card without damaging it beyond repair.

Cards that are photolithographically pre-recorded could be protected from unauthorized duplication through hardware detection of pre-recorded versus locally written data. Optical memory cards could be made even more secure by increasing the surface reflectivity of the Drexon® material (typically 40%) during the manufacturing process to produce an "optical watermark" pattern to further prevent counterfeiting. [Ref. 25: p. 21]

The MSC is not so fortunate. Equipment for reading, altering or duplicating data stored on MSCs is readily available or easily constructed from parts available at any local electronic supply store. In an effort to increase worldwide acceptance in the banking industry, certain national and international standards for encoding data are in widespread use in MSC systems [Ref. 8]. These standards are also applied in many non-banking applications of MSC systems and are readily available to potential abusers of the system. Regardless of the data encoding scheme used, data contained in an MSC is still susceptable to compromise by the ease of physical access to it.

In direct contrast to the passive memory card technologies, IC cards contain components that must be electronically active for physical access operations to take place. These components generate compromising signals and so the cards must be used in TEMPEST approved environments to prevent the compromise of sensitive data. Of course, if the level of TEMPEST security is not an issue for a particular application then these signals are not a problem. With the IC card's potential for high levels of logical security, the additional cost incurred by using TEMPEST approved systems that exploit this feature would be warranted.

b. Environmental Factors

A second issue in the area of physical security is the sensitivity of these storage media to environmental factors such as: Temperature, EMP, EMI, X-rays and ED.

24

(1) *Temperature.* None of the technologies discussed here are fireproof. The optical memory card is sensitive to temperatures near 200° C and above due to the melting point of its laser recording medium. Low temperature limits for the lasercard are a function of the low temperature fracture limits of the materials used in their manufacture. IC cards are limited primarily by the operating temperature range of the integrated circuits they contain. MSCs are temperature limited by the plastics used in their manufacture.

(2) *Electromagnetic Pulse (EMP).* Electromagnetic Pulse (EMP) is a term that refers to the intense electromagnetic field generated by the detonation of nuclear weapons. This field travels away from the point of detonation in the form of a wideband, high-amplitude, short-duration pulse of electromagnetic energy. The degree of damage inflicted on a particular piece of equipment is primarily a function of the distance of the equipment from the point of detonation.

Of the three technologies discussed, the optical memory card is the only one not affected by EMP. However, the optical memory card's immunity to EMP does not extend to the equipment used to read and/or write on it.

(3) *Electromagnetic Interference (EMI).* Electromagnetic interference appears in the form of electromagnetic waves of varying amplitudes and wavelengths that are generated by electrical and electronic equipment. The same holds true for any current carrying conductor. The amount of interference experienced by a particular storage medium is primarily a function of the strength and location of the EMI emitter relative to the storage medium and how well the storage medium is shielded from EMI.

Optical memory cards are not affected by EMI. MSCs are only affected by EMI fields large enough to overcome the coercivity (resistance to magnetization) of the magnetic stripe at a level sufficient to alter the data stored on it. IC cards are susceptible to EMI fields of sufficient strength to induce errors into data being transferred on internal and external busses or cause actual damage to the ICs themselves.

(4) *X-Ray Radiation.* Optical memory cards are not affected by X-ray radiation. IC cards, like other semiconductor devices, can be severely damaged by high-energy X-rays as they pass through their integrated circuits. MSCs can be damaged by X-ray emitters in varying degrees, depending on the intensity of the X-ray source.

(5) *Electrostatic Discharge (ED)*.   Electrostatic Discharge (ED) damage is a phenomenon associated only with IC cards. Electrostatic potentials of up to 15,000 volts can be accumulated on the human body and discharged into the card by the simple act of transferring the card from one person to another. This discharge can severely damage the semiconductor components of the card. Testing to date has produced results indicating that only a small number of manufacturers make cards capable of withstanding even a 10,000 volt ED. [Ref. 26: p. 121].

c. *Intentional/Unintentional Destruction of Data*

Intentional/unintentional destruction of data, whether for security reasons or by agents of a subversive organization, can be accomplished in several ways: Optical memory cards can be burned, shredded, mutilated or overwritten (the equivalent of writing a pit in every position). IC cards and MSCs can be destroyed by exposure to any of the environmental factors discussed earlier that would result in the physical destruction of the card and its components or the effective neutralization of the storage medium. Non-destructive alteration of data for subversive purposes, as the following section suggests, is not as easy as complete destruction.

2. Logical Security

Logical security, in the context of this study, relates to the logical safeguards employed in each memory card technology to prevent unauthorized access or manipulation of data stored on the card. Logical security will be discussed in the following areas: Systems Access and Access Leveling, Data Encoding and Encryption. The limited capacity of the MSC restricts systems that employ this technology to using relatively simple system access and data encoding schemes. Since most of the material in this section is not directly applicable to MSCs, that medium will not be discussed.

Bear in mind that most of the systems access, access leveling, data encryption and encoding methods discussed are a function of software. As such, they can be implemented on either optical memory card or IC card systems with an equal expectation of success, the major difference being where the processing takes place -- on or off the card.

a. *System Access and Access Leveling*

System access and access leveling techniques focus mainly on indentification of the entity, human or computer, attempting to gain access to data contained on the memory card and control of the level of data access the entity is entitled to.

26

b. Data Encoding and Encryption

Data encoding defines the format used for representing the data as it is stored in the memory card. For example, the American Standard Code for Information Interchange (ASCII), along with any system-specific parity or error-checking bits, is a data encoding scheme.

. Data encryption techniques define the algorithm and keys used to encrypt the data before it is encoded and stored on the card. The details of implementing these algorithms and keys are beyond the scope of this thesis. However, essentially, encryption techniques allow data to be put into a secure form, stored on the card and decrypted only by a system with knowledge of the algorithm and keys. A simple example would be an A, A-1 type of algorithm that positively displaces the ASCII code for each character by two, the encrypting key (assume modulo 128). To decrypt the algorithm, the system receiving the data would subtract two from each ASCII character (the decrypting key) to recover the original data. The algorithm and its associated keys could be stored on the memory card, or just the keys [Ref. 28: p. 2-3].

As stated previously, any of the system functions discussed above could be implemented on optical memory card or IC card systems. Assuming the memory is available to implement the particular technique desired. The major issue is the sophistication of the hardware. IC card systems require very little in the form of external hardware since the processing of security access and data encryption algorithms takes place on the card itself.

C. HARDWARE REQUIREMENTS

This discussion will focus on the hardware requirements for optical memory cards and IC cards. MSCs have essentially the same hardware requirements as optical memory cards in that they must be used in systems supported by a host computer and have no processing capability of their own. They are interfaced using industry standard serial interfaces.

The optical memory card requires a hardware reader or reader/writer unit to facilitate the actual transfer of data to and from the card. This is usually accomplished by using a device that is peripherally connected to a host computer system. This device contains the electro-optical/mechanical parts required to perform the physical data transfer function and the logic circuitry required to address and prepare the data for transfer to the host computer. (See Table 2) Data is usually transferred to the host

System access control is mainly a matter of providing the system with the means to accurately determine the identity of the entity attempting to gain access to the system. The more secure the system needs to be, the more sophisticated the system access controls required. Here are some access control techniques that could be used with memory card systems and the amount of memory they require [Ref. 27: p. 5]:

- Password/Personal Indentification Number (PIN) -- Varies with the length of the password or PIN
- Digitized Fingerprint/Retina Scan -- 25 kbits
- Digitized Signature -- 25 kbits
- Digitized Voiceprint -- 50 kbits
- Digitized Photograph -- 50 kbits

Of the techniques described above, the only one currently used with IC cards is the PIN. Implementations of the password/PIN essentially compare a user entry to a password or PIN stored in card memory to determine the access rights of the user. If the entry matches, the user is granted access. If the entry doesn't match, the user is given further opportunities to make the correct entry. After a predetermined number of incorrect entries are made the card locks itself and must be returned to the issuing authority to be unlocked. Some PIN implementations allow the user to change the PIN at will, thus increasing the security of the system. The other techniques perform essentially the same function with greater personalization of the access criteria. These more sophisticated techniques could easily be implemented on optical memory card systems and still leave a substantial amount of memory capacity for user data. Implementing these techniques using memory card technology can be especially advantageous to large organizations. DoD for example, which has a large and highly mobile user population with a variety of security clearances, would benefit from such a system because it places personal access data in the custody of the individual and reduces the requirement for on-line access verification systems [Ref. 28: p. 2].

Access leveling is a technique that divides the available card memory into limited access segments, allowing access only to entities that meet the access criteria defined for that access level. See the financial transaction card example in the previous chapter.

using RS-232C, Small Computer Serial Interface (SCSI), or PC compatible type serial interfaces. Data transfer speeds are typically 100 kbits per second for read operations

---

TABLE 2
COMPARISON OF MEMORY CARD HARDWARE REQUIREMENTS

OPTICAL MEMORY CARD
(PC Compatible Unit)

Type of device: Read Only, semiconductor laser (low-power), CCD

Read /Write, semiconductor laser (dual-power), CCD

Type of Host Interface: Serial, IBM Compatible, RS-232C, SCSI

Data Transfer Rate: Read, typically 100 kbits/sec.

Write, typically 8-10 kbits/sec.

Access Time*:   Typically 1 sec.

INTEGRATED CIRCUIT (IC) CARD

Type of device: Read /Write, provides serial communications with on-card chips. Also provides Vcc, Vpp, clock and control signals.

Type of Host Interface: Serial, typically RS-232C

Data Transfer Rate: Typically 1200,2400,9600 bits/sec. Depends on system design.

Access Time*:   Typically 100μsec.

MAGNETIC STRIPE CARD (MSC)

Type of device: Read/Write, magnetic head.

Type of Host Interface: Serial

Data Transfer Rate: Varies with speed of card through device.

Access Time*:   Variable (sequential storage medium)

* Time to locate a given memory location.

---

and 8-10 kbits per second for write operations. These figures are for production prototype PC-compatible units. Card access times are typically one second. [Ref. 29: p. 36-38]

The IC card also requires a reader/ writer unit that can function as an on-line terminal for a computer system or a stand-alone unit for off-line applications. The reader/writer essentially acts as a communications interface providing I/O signals Vcc and Vpp voltages, clock and control signals. Data is transferred using predominantly RS-232C serial interfaces at speeds from 1200 to 9600 bits per second. (See Table 2) [Ref. 29: p. 36-38]

29

D. ECONOMIC FACTORS

There are two major economic issues relative to optical memory cards and IC cards. Cost and Availability. They apply to both the memory cards themselves and their associated hardware. These issues do not apply to MSCs because the maturity of that medium has stabilized its cost and availability in the marketplace.

1. Cost

Comparative costs for optical memory and IC cards are based on capacities and features. (See Table 3) Optical memory card costs range from $1.00 for blank (pre-formatted) cards to $5.00 for 2.2 Mbyte cards. IC cards run anywhere from $3.00 - $5.00 for 8 kbyte MCU cards to $8.00 for a 16 kbyte MCU card. This gives a price per bit ratio of 5.68×10^{-6} cents for blank cards to 2.84×10^{-5} cents for 2.2 Mbyte (17.6 Mbit) pre-recorded cards. The price per bit ratio of an 8 kbyte (64 kbit) card is

---

TABLE 3
ECONOMIC COMPARISON OF MEMORY CARDS

MEMORY CARD TECHNOLOGY	COST	AVAILABILITY
OPTICAL		
MEDIUM (Cents/Bit)	5.68×10^{-6} (Blank 2 2Mbyte Cards) 2.84×10^{-5} (2.2 Mbyte card, pre-recorded)	Limited to single supplier (DTC)
HARDWARE (Industry Estimate)	Read Only, typically $200 Read/Write, typically $500-$1000	Limited to quantity orders. Expect comm'l. avail. Q-IV '87 (cy)
INTEGRATED CIRCUIT		
MEDIUM (Cents/Bit)	1.88×10^{-2} (8kbyte MCU card) 6.25×10^{-3} (16kbyte MCU card)	Good. Manufactured domestically. Also in Europe and Japan.
HARDWARE (Industry Estimate)	On-line, $100 Off-line (PC compatible), $40	Limited to quantity orders.

1.88×10^{-2} and 6.25×10^{-3} for 16 kbyte (128 kbit) cards. In these terms, the optical memory card presents a clear advantage over the other two in cost per unit of storage. This can be attributed to the smaller manufacturing costs associated with the production of a storage medium that doesn't use semiconductor technology.

30

Comparative costs for optical memory card and IC card readers and reader/writers are based on function. The differentiation between read-only devices and read/write devices doesn't apply to IC card systems because the same device can be used to perform both functions. These units average $100 for units intended for use in on-line host computer applications and as low as $40 for units intended for use in off-line stand alone applications with terminals or PCs. Read-only units for optical memory cards are projected to be initially around $200 and read/write devices $500-$1000. (See Table 3) In late 1985, a large health insurance firm received the first of 60,000 reader/writ~ units to be delivered by a large Japanese manufacturer by mid to late 1987 at an average price of less than $700 each. [Ref. 30: p. 12]. The substantial differential between hardware costs of these two technologies is another result of the passive/active nature of their storage media as well as their relative maturities. The optical memory card, being a passive storage medium requires more technology in the reader/writer unit than the more complex active storage medium used in the IC card. Also, IC card hardware is more mature in the marketplace than optical memory card hardware.

2. Availability

Optical memory cards capable of both read and write operations are currently available only from DTC and are manufactured in a single facility located in Mountain View, California. This facility is capable of a maximum output of 100,000 optical memory cards per day [Ref. 31: p. 9]. A read-only optical memory card was introduced in Japan in 1985 by a large Japanese printing firm which intends to market the product for use in electronic books. [Ref. 32: p. 32]. DTC has indicated a willingness to enter into second-sourcing agreements with their licensees [Ref. 31: p. 9].

IC cards have been in use for some time in Europe and Japan. Manufacturers in these areas produce a wide variety of IC card products. IC cards have entered the U.S. market in recent years with several large banking firms running market tests. The U.S. Army has recently tested an 8 kbyte chip for use as an identification tag in its Individually Carried Record (ICR) program. The IC card is readily available from several U.S. and foreign manufacturers in several standard forms. Most manufacturers will accept quantity orders for custom cards designed for specific applications. The same availability is enjoyed by read/write equipment from essentially the same companies. (See Table 3) [Ref. 29,28: p. 36-38,6]

As an overall comparison it is clear that each memory card technology is best suited for a particular range of applications. MSCs are good for low cost, low data density and low security applications. IC cards provide solutions for medium data density, highly secure data storage and communication applications that require a minimum of external electronics. Optical memory cards present an opportunity for high density data storage with minimal weight and cube storage requirements. If additional security is needed, optical memory card systems can implement a number of highly sophisticated biometric parameters to control access to the data stored on them.

The next chapter will explore two possible optical memory card applications suitable for a military environment.

IV. POTENTIAL MILITARY APPLICATIONS

A technical document publishing, distribution and update program and an individual personnel record storage and update system are two potential military application areas for optical memory card systems. The first, adapted from Ref. 30, is an area where industry analysts feel the optical memory card will have the greatest impact on the marketplace. This application will focus on the process of getting a document from the final draft stage, as output from a Computer Aided Publishing (CAP) system, to the ultimate user organization along with any subsequent changes or updates. The discussion will address this process as it relates to both classified and unclassified documents.

The second application is the extrapolation into a military context of a program being implemented by a large Northeastern health insurance organization. This program is currently the only widely publicized commercial commitment to a large-scale implementation of an optical memory card based system by a U.S. company. A program similar to this is currently being undertaken by the U.S. Army. Called the Individually Carried Record (ICR) program, it uses IC tags worn around the neck to store basic personnel data.

A. A TECHNICAL DOCUMENT PUBLISHING, DISTRIBUTION AND UPDATE PROGRAM

In managing and using large, library-sized data bases it is usually unneccessary, and in most cases undesirable, for a particular user to have access to the entire data base. Using aircraft maintenance facilities as an example, more information is required at a depot level maintenance facility than at an organizational level facility. Consequently, at the organizational level there is less information to manage and it is used in book-sized and even page-sized quantities.

To make the "paperless ship" concept a reality, a mass storage medium is needed to replace the literally tons of paper technical manuals and directives carried aboard the average naval frigate. Other optical media, CD-ROM for example, have been proposed as solutions to the mass storage problem. These other media have what would in previous years have been called an incredible storage capacity. A single CD-ROM can store 270,000 pages of text [Ref. 33: p. 25]. Distributing a single manual in

a CD-ROM format is neither cost effective nor logical from a user perspective. A storage medium like a 2.2 Mbyte optical memory card that holds 800 pages of text or 200 pages of combined text and graphics is more logical from a user point of view. Such a system could be used to produce classified and unclassified documents. Revisions and interim changes made to a digital medium would virtually eliminate the time and energy spent making pen-and-ink and replace-page changes to technical manuals and directives.

1. Unclassified Documents

The first step in publishing a document for use with an optical memory card system would be preparation of the final document using a Computer Aided Publishing (CAP) software package. (See Figure 4.1) The output from the CAP is transferred to
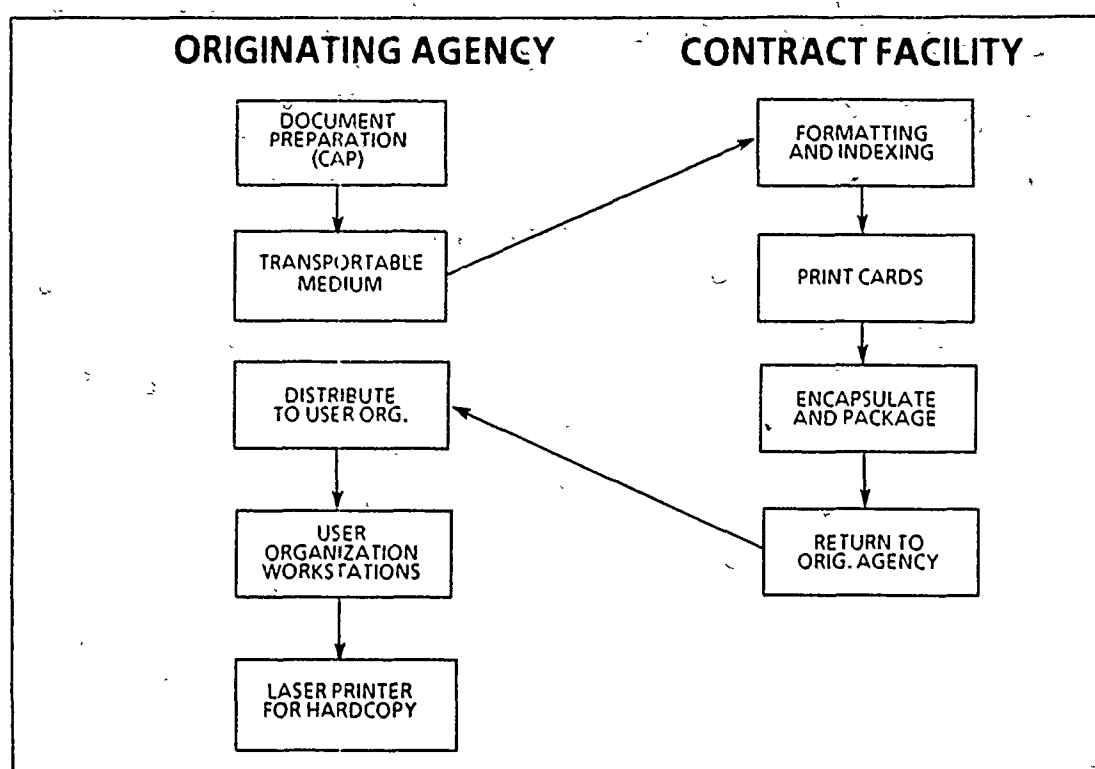

Figure 4.1   Unclassified Document Publishing Process.

some form of transportable digital storage medium, nine-track tape for example. The document is then shipped to a contract mass production optical memory card publishing facility. DTC is presently the only organization with the facilities to mass produce pre-recorded optical memory cards. The contract facility would format and

34

index the data according to the contract specifications. A run of cards would then be printed, encapsulated, packaged and returned to the originating agency. The originating agency then distributes the cards to the appropriate organizations. A receiving organization could use the card in a desktop-size (personal computer) or smaller, portable, document handling workstation. A user needing personal copies of a particular document could print them using an inexpensive desktop laser printer.

Revisions and interim changes could be published in essentially the same manner. (See Figure 4.2) An organization receiving a change to a document would
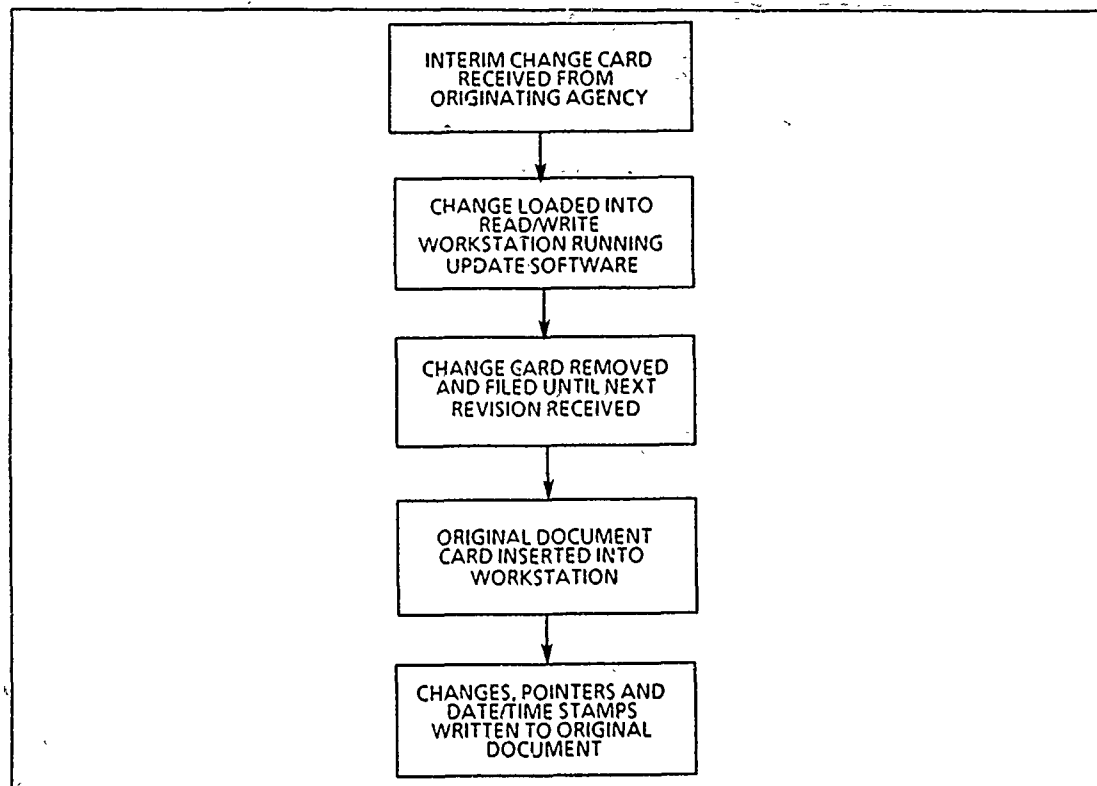
Figure 4.2 Document Updating Process.

place the card containing the change into a workstation with read, write capability and run a document updating software package. After the changes have been loaded into the workstation's memory the user would remove the card containing the changes and file it until the next revision is received. The original document is then inserted into the workstation and the changes are written to an unused portion of the card. Pointers and date/time stamps would also be written along with the changes to allow the card-reading software to identify the most recent changes for a particular section of the document.

A word about indexing: The lower the level of an index, word vice chapter for example, the greater the amount of storage space required to store it. For a document that is indexed on chapters or sections the index would be relatively simple and would require very little storage space. A document that is indexed on words could easily have an index that is larger, in terms of storage space required, than the document itself. A tradeoff point must be identified, for example page-level indexing, and changes issued at that level. Document program monitors at the originating agency would need to issue a revised document card incorporating all the current changes before the previous card was filled to capacity.

2. Classified Documents

Taking into account the security requirements associated with classified documents, the publishing process would have to be performed in-house. (See Figure 4.3) The document is prepared using CAP software running on TEMPEST approved


```
┌─────────────────────────┐
│   DOCUMENT              │
│   PREPARATION           │
│   (CAP/TEMPEST)*        │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│   CAP OUTPUT DIRECT     │
│   TO LASER CARD         │
│   DUPLICATOR            │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│   DOCUMENT             │
│   DUPLICATED ON         │
│   PRE-FORMATTED         │
│   BLANK CARDS           │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│   DISTRIBUTE CARDS      │
│   TO USER               │
│   ORGANIZATIONS         │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│   LASER PRINTER         │
│   FOR HARDCOPY          │
└─────────────────────────┘

* Process is the same for update and revision publishing.
```
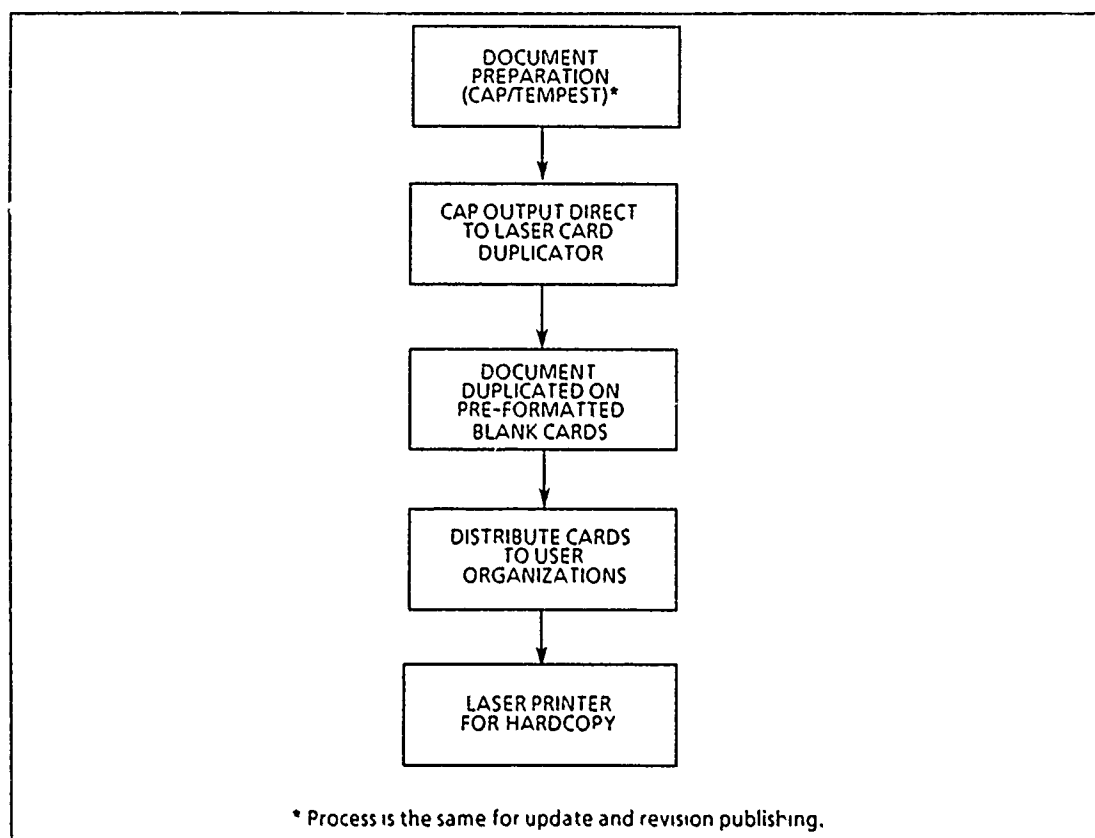
Figure 4.3   Classified Document Publishing Process.

computing facilities. The output from the CAP system is sent to a TEMPEST approved high-speed laser optical memory card duplicator which transfers the document to pre-formatted blank cards in a manner similar to a laser printer writing to paper. The cards can then be distributed in a manner commensurate with their classifications. Revisions and interim changes can be published and distributed in the same fashion. (See Figure 4.3)

By way of comparison for in-house publishing, the Kodak Model 225 and Xerox Model 8700 photocopiers have copy rates of 70 pages per minute. (See Table 4)

TABLE 4

COMPARISON OF IN-HOUSE DUPLICATING METHODS

KODAK MODEL 225
XEROX MODEL 8700

Copy Rate: 70 pages per second

Time Required to Copy 200 page Manual: 2.8 min.
(Combined text and graphics)

LASER OPTICAL MEMORY CARD
DUPLICATOR

Copy Rate: 100 Kbits/sec.

Time Required to Duplicate a Single 2.2 Mbyte Card: 2.9 min.
(200 pages combined text and graphics 800 pages, text only)

At that rate, a 200-page manual containing combined text and graphics could be duplicated in 2.8 minutes. A high-speed (100 kbit per second) laser optical memory card duplicator could produce the same manual, or an 800-page manual containing only text, in 2.9 minutes. [Ref. 30: p. 10]

An additional benefit gained from the use of such a system would be a dramatic reduction in the space required to store documents aboard ships. (See Table 5) Converting the 30,393,000 pages of documents required per ship [Ref. 33: p. 27] to dual sided 4.4 Mbyte optical memory cards would reduce the storage space required from 4,222 yards to 21 yards, a factor of over 200! Optical memory cards would also provide benefits in weight savings and increased longevity. An optical memory card weighs less than an ounce and has a *minimum* service life of over five years of continuous use in the most severe geographic climates with no degradation in readability [Ref. 9: p. 2].

```
                        TABLE 5
         NAVAL SHIP'S TECHNICAL MANUAL (NSTM) DOCUMENT
           REQUIREMENTS - PAPER VS. OPTICAL MEMORY CARDS
```

PAPER

Number of Document PAGES required per ship: 30,393,000*

30,393,000 pages ÷ 500 pages/ream = 60,786 reams/ship

60,786 reams × 2.5 inches/ream = 151,965 inches/ship

151,965 inches ÷ 12 inches/foot = 12,664 feet/ship

12,664 feet ÷ 3 feet/yard = <u>4,222 yards/ship</u>

OPTICAL MEMORY CARD

30,393,000 pages/ship ÷ 1,600 pages/card† = 18,966 cards/ship

0.04 inches/card‡ × 18,946 cards/ship = 760 inches/ship

760 inches/ship ÷ 12 inches/foot = 63 feet/ship

63 feet/ship ÷ 3 feet/yard = <u>21 yards/ship</u>

*From Naval Ship's Technical Manual statistics

†Width of card plus 2 mil plastic sleeve

‡Dual-sided 35mm optical stripe, 2 2 Mbytes per side

B. AN INDIVIDUAL PERSONNEL RECORD STORAGE AND UPDATE PROGRAM

Quoting Barnes and Sukernick in Ref. 34:

> On May 6, 1985 Blue Cross and Blue Shield of Maryland, Inc. announced the
> LifeCard®, a unique personal medical history and insurance benefits card. . . .
> On December 6, 1985, Canon, Inc. of Japan . . . delivered the first write/read
> optical card peripheral [of 60,000] to Blue Cross/Blue Shield of Maryland for its
> LifeCard® system.

The Blue Cross/Blue Shield of Maryland (BC/BSM) LifeCard® is the first commercial application of optical memory card technology in the U.S. The LifeCard® system stores routine and critical health data, treatment and prescription audit trails and insurance coverage and benefits. BC/BSM intends to issue LifeCards to all of its 80 million members and estimates equipment demand will be as high as 750,000 units [Ref. 34: p. 3]. The LifeCard® is intended to be used by hospitals, clinics, doctor's offices and pharmacies to provide faster, better, and less expensive health care to the patients covered by BC/BSM [Ref. 34: p. 1]. BC/BSM chose the optical memory card for the LifeCard® program for its memory capacity (2.2 Mbyte version) and the possiblities for later memory capacity expansions [Ref. 34: p. 2].

To the DoD and other government agencies considering optical memory cards as a solution to the reduction of paperwork the BC/BSM LifeCard® program is an important first step in proving the technical and commercial viablity of optical memory card systems. The success of the LifeCard® will provide justification for conducting studies and pilot projects for developing the optical memory card for use in the government sector.

One application that could be derived from the BC/BSM LifeCard® program is an individually carried personnel record card. The card could have human-readable information on one side, such as the photograph and other information present on a military I.D., and an optical stripe on the other side [Ref. 35: p. 6]. The card could be partitioned to provide storage space for:

- Digitized Photograph or Other Biometric Data
- Service Record Data
- Pay Record Data
- Training Record Data
- Medical Record Data
- Dental Record Data
- Security Clearance and Access Data
- Commissary and Exchange Privilege Data

The card could be used for identification, determining commissary/exchange privileges and access control for security systems as well as providing personal and service related historical data. (See Figure 4.4)


```
        FRONT                BACK
     DIGITAL DATA       EYE-READABLE DATA

   Biometric Data      Photo
   Service Record      Signature
   Pay Record          Social Security Number
   Training Records    Date of Birth
   Medical Record
   Dental Record
   Security Clearance and Access Data
   Commissary and Exchange Privilege Data
```
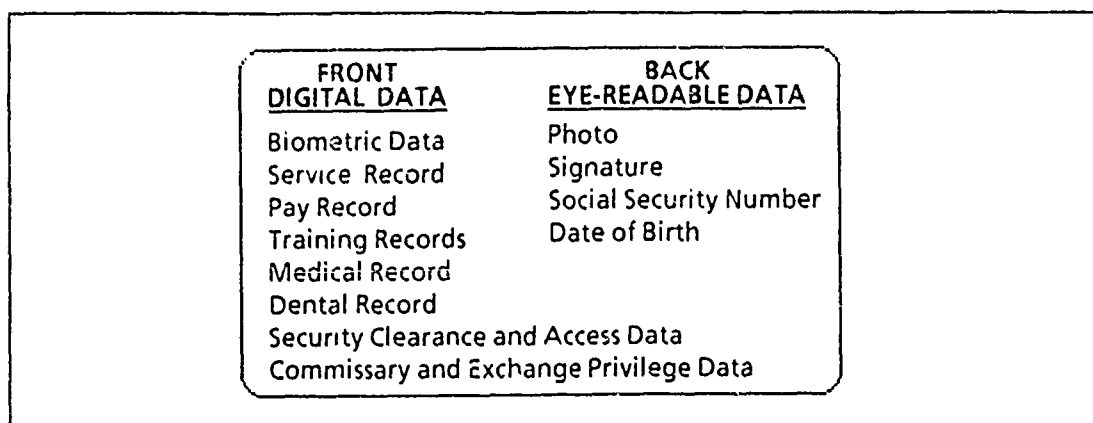
Figure 4.4   Contents of the Individual Personnel Record Card.

Cards could be updated and verified with a centralized data base on a periodic or transactional basis to keep them and the data base sufficiently "backed-up" to provide data to replace lost, stolen or mutilated cards.

The optical memory card has the potential for meeting the military needs for recording and tracking personnel data. How great that potential is will depend upon the success of BC/BSMs LifeCard® program and others yet to be conducted in the government sector.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The optical memory card is on the edge of a revolution in mass storage technology. While currently overshadowed and sometimes confused with CD-ROM and other optical disk technologies, the optical memory card will eventually find its place as a book-sized storage medium. However, there are still two major obstacles the optical memory card must overcome before it can become a hard competitor in the optical memory market: Availability and Standardization. As of this writing, optical memory card hardware availability is limited and attempts to standardize it are restricted to the efforts of a small ANSI working group [Ref. 34: p. 3]. As with all new technologies, if they are even moderately successful, availability will increase with demand and some standard, de facto or otherwise, will emerge in the interest of economic competition.

With these two problems resolved, the optical memory card presents a great potential for the storage of book-sized packets of information. Many information systems that store and distribute data present an opportunity to employ this technology.

B. RECOMMENDATIONS

One of the original objectives of this study was to actually publish the thesis in its entirety on a single optical memory card as a proof-of-concept demonstration of the local publishing capabilities of a PC-based optical memory card system. That objective could not be met because of the unavailablity of reader/writer units and the software to drive them. This topic is meaningful, especially in the light of increased activity in support of the "paperless ship" program.

LIST OF REFERENCES

1. Black, N., "Pursuit of the 'Paperless Ship' -- Admiral Aims to Clear Decks of Document Burden", *The Washington Post*, May 5, 1987.

2. Dorsey, J., "Navy Acts to Erase Paper From Ships". *The Ledger Star*, April 6, 1987.

3. Department of Defense, *CALS Core Requirements (Phase I.0) [Coordination Draft]*, Department of Defense, Washington D.C., March 1987.

4. Aveney, B., "A Conversation with Robert B. Barnes", *Electronic Publishing Business*, Vol. 3, No. 1, January 1985.

5. Barnes, R. B.,"There's a Laser Card in Your Future", *Electronic Publishing Review*, Vol. 4, No.1, 1984.

6. Barnes, R. B., *"The Optical Memory Card - It's Future is Becoming Clear"*, paper presented at the Fourth Annual Technology Opportunity Conference on the Future of Optical Memory Technology, San Francisco, Califonia, July 1986.

7. Drexler, J.,"Laser Card for Compact Optical Data Storage Systems", *SPIE Vol. 329 Optical Disk Technology (1982)*, SPIE, 1982.

8. American National Standard Specification ANSI X4.16-1983, *American National Standard for Financial Services - "Financial Transaction Cards - Magnetic Stripe Encoding"*, 1986.

9. Unknown, "Technical Information -- How Much Information Can a LaserCard® Hold?" *Drexon LaserCard® Summer Update*, Drexler Technology Corp., August 1987.

10. Scherwin, J. B., "The Potential Role of Drexon LaserCards® in Optical Publishing", *Videodisc and Optical Disk*, Vol. 5, No. 4, July-August 1985.

11. Mayer, M., "Here Comes the Smart Card", *Fortune*, Vol. 108, No. 3, August 8, 1983.

12. McIvor, B., "Use of EEPROM Technology in Smart Card", *Electrol 85 and Mini/Micro Northeast*, IEEE, April 23-25, 1985.

13. Iovacchini, A. and Goldberg. J., "Visa, Mastercard Battle Over Future Technology of Bank Cards", *Bank Systems and Equipment*, Vol. 22, No. 11, November 1985.

14. Artusi, D., "The Technology of Smart Cards and Their Applications", *Electro/85 and Mini/Micro Northeast*, IEEE, April 23-25, 1985.

15. Glazer, S., "Smart Cards", *High Technology*, Vol. 6, No. 7, July 1986.

16. Asano, S., "Technological Trends and Applications of the IC Card", *Office Equipment and Products (Japan)*, Vol. 15, No. 94, August 1986.

17. Wittfeld, P., "Smart Cards Today and in the Future", *Magazine of Bank Administration*, Vol. 62, August 8, 1986.

18. Svigals. J. and Ziegler, H. A., "Magnetic-Stripe Credit Card: Big Business in the Offing", *IEEE Spectrum*, Vol. 11, No. 12, December 1974.

19. American National Standard Specification ANSI X4.13-1983, *"Financial Services - Financial Transaction Cards"*, 1983.

20. Telephone conversation April 11, 1987 with Mr. Chuck Keller, Chief Design Engineer, Drexler Technology Corporation.

21. Chief of Naval Operations Instruction 5239.1A, *Security Requirements for ADP Systems*, Department of the Navy, August 3, 1982.

22. Arimura, K., "IC Cards Could Change the Way You Live and Work", *Office Equipment and Products*, Vol. 15, No. 89, March 1986.

23. Unknown, "New Card Security Feature Seen as Major Fraud Deterrent", *Bank Systems and Equipment*, Vol. 12, No. 12, December 1975.

24. Iovacchini, A., "Magnetic Stripe Faces New Threats as Security, Capacity are Challenged", *Bank Systems and Equipment*, Vol. 22, No. 7, July 1985.

25. Barnes, R.B. and Sukernick, F.J., "LaserCard® Automated Publications and Maintenance Records", *1985 Videodisc Conference Proceedings*, Videodisc, Optical Disk and CD-ROM Conference and Exposition, 1985.

26. Jeffreys, D.C. and Tschirch, R.P., "Reliability and Security of Smart Cards - Laboratory and Field Results", *1986 IEEE International Conference on Consumer Electronics*, June 4, 1986.

27. Barnes, R.B., Kilty, L.R., *"Tomorrow's Air Travel Card"*, paper presented to the Card Systems Technical Task Force of the Universal Air Travel Plan, Washington, D.C., April 1986.

43

28. Guion, C., "Smart Cards and Security", *Mini/Micro Northeast Computer Conference and Exhibition*, IEEE, May 13-15, 1986.

29. Unknown, "Spotlighting IC, Laser Cards and Its Reader/Writer", *Office Equipment and Products (Japan)*, Vol. 15, No. 94, August 1986.

30. Barnes, R.B. and Sukernick. F.J., *"The Optical Memory Card -- Its Role in the Distribution of Technical Information"*, paper presented to the American Defense Preparedness Association (ADPA) Annual Conference of the Technical Documentation Division, 28th, Orlando, Florida, May 1986.

31. Drexler Technology Corporation, *Annual Report*, 1986.

32. Kuramochi, W., "Laser Memory Card Offer Alternatives for Compact, High-Capacity Storage", *Office Equipment and Products (Japan)*, September 1985.

33. Lind. D.J., *"Optical Laser Technology, Specifically CD-ROM, and Its Application to the Storage and Retrieval of Information"*, Master's Thesis, Naval Postgraduate School, Monterey, California, June 1987.

34. Barnes, R.B. and Sukernick, F.J., *"The Optical Memory Card - Its Role in Medical Record and Information Systems"*, paper presented to the Society for Applied Learning Technology Conference on Learning Technology in the Health Care Sciences, 1st, Arlington, Virginia, April 1986.

35. Barnes, R.B. and Kilty, L.J., *"The Driver's License for the Nineties"*, paper presented to the American Association of Motor Vehicle Administrators at the International Driver License/Driver Control Workshop, Reno, Nevada, March 1986.

BIBLIOGRAPHY

Barnes, R.B., *"Desktop Publishing -- Is All This Paper Really Necessary?"*, paper presented at the Annual TechDoc Conference of the Graphic Communications Association, 11th, San Francisco, California, August 1987.

Barnes, R.B., *"The Magic Card -- Possiblities for Publishing"*, paper presented to the Society fo Scholarly Publishing (SSP) Annual Meeting on Seeking Scholarly Perspectives, 8th, San Francisco, California, May 1986.

Barnes, R.B., Sukernick, F.J., "Files on a Card: Small Format, High Capacity Digital Storage/Retrieval", *Journal of Information & Image Management*. Vol. 19, No. 10, October 1986, p. 34.

Barnes, R.B and Field, R.C., *"The Optical Memory Card -- A Unique Publishing Medium"*, paper presented at the International Meeting for Optical Publishing and Storage (Optical '87), Amsterdam, The Netherlands, April 1987.

Frenger, P., "The Computerized Medical Record-On-A-Card", *Rocky Mountain Bioengineering Symposium*, 22nd, International Proceedings, IEEE, 1985, pp. 131-135.

Gal, E. and others, "Realization of Electro Optical, Digital Information Storage System", *Convention of Electrical and Electronics Engineers in Israel*, 14th, EEE, 1985, sec. 4.3.3.

McIvor, R., "Smart Cards", *Scientific American*, Vol. 235, No. 5, November 1985. pp. 152-159.

Tamada,T., "Increasing Application of IC Cards Brings Moves to Standardize IC Cards", *Office Equipment and Products (Japan)*, Vol. 14, No. 77, March 1985, pp. 35-36,88.

Unknown, "Optical-Card Reader Uses New Technology" *PC Week*, March 31, 1987, p. 22.

Unknown, "Canon Supplies World's First Optical Card Reader-Writer", *Office Equipment and Products (Japan)*, February 1986.

Unknown, "Dai Nippon Develops Optical Memory Card", *JEE*, August 1985, p. 24.

Unknown, "Toshiba Introduces Laser Memory Card Reader/Writer", *Japan Economic Journal*, June 14, 1986.

Unknown, "Publishing with the Optical Memory Card: An Update", *Electronic Publishing Business*, Vol. 4, No. 10, November 1986, pp. 4-6.

Unknown, "IC Cards Continue to Find New Application Areas", *Office Equipment and Products (Japan)*, Vol. 14, No. 86, December 1985, pp. 42-47.

INITIAL DISTRIBUTION LIST

No. Copies

1. Defense Technical Information Center 2
   Cameron Station
   Alexandria, VA 22304-6145

2. Library, Code 0142 2
   Naval Postgraduate School
   Monterey, CA 93943-5002

3. Chief of Naval Operations (OP-945) 1
   Department of the Navy
   Washington, D.C. 20350

4. Commander, Naval Military Personnel Command 1
   NMPC (NMPC-16B94)
   Attn: LT Jenny Mertz, RAPIDS Program Officer
   Room 4061
   Washington, D.C. 20370

5. LT Stephen H. Frink 3
   Naval Air Reserve
   NAS Norfolk
   Norfolk, VA 23511-5797

6. Barry A. Frew 4
   Administrative Sciences Department
   Code 54FW
   Naval Postgraduate School
   Monterey, CA 93943

7. Dr. Lang C. Chou 1
   Department of Meteorology
   Code 63CQ
   Naval Postgraduate School
   Monterey, CA 93943

8. Deputy Chief of Naval Operations 1
   (Surface Warfare)
   Department of the Navy
   Washington, D.C. 20350-2000

9. Mr. Herbert C. Frink 1
   13651 N.E. 1st Avenue
   Miami, FL 33161

46

10. LCDR David J. Lind, USN   1
    Naval Data Automation Command (Code 30)
    Washington Navy Yard
    Washington, D.C. 20374-1662

11. United States Military Academy   1
    Department of Geography and Computer Science
    Attn: CPT Peter B. Polk, USA
    West Point, NY 10996-1695

12. CPT Bruce A. Whitehouse, USMC   1
    MCOTEA
    H & S Battalion
    MCDEC
    Quantico, VA 22134